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Hospital Staffing and Health Care–Associated Infections: A Systematic Review of the Literature

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Background: Previous literature has linked the level and types of staffing of health facilities to the risk of acquiring a health care–associated infection (HAI). Investigating this relationship is challenging because of the lack of rigorous study designs and the use of varying definitions and measures of both staffing and HAIs.

Methods: The objective of this study was to understand and synthesize the most recent research on the relationship of hospital staffing and HAI risk. A systematic review was undertaken. Electronic databases MEDLINE, PubMed, and the Cumulative Index to Nursing and Allied Health Literature (CINAHL) were searched for studies published between January 1, 2000, and November 30, 2015.

Results: Fifty-four articles were included in the review. The majority of studies examined the relationship between nurse staffing and HAIs ($n = 50$, 92.6%) and found nurse staffing variables to be associated with an increase in HAI rates ($n = 40$, 74.1%). Only 5 studies addressed non-nurse staffing, and those had mixed results. Physician staffing was associated with an increased HAI risk in 1 of 3 studies. Studies varied in design and methodology, as well as in their use of operational definitions and measures of staffing and HAIs.

Conclusion: Despite the lack of consistency of the included studies, overall, the results of this systematic review demonstrate that increased staffing is related to decreased risk of acquiring HAIs. More rigorous and consistent research designs, definitions, and risk-adjusted HAI data are needed in future studies exploring this area.

Health care–associated infections (HAIs) are a serious patient safety issue that result in increased morbidity and mortality as well as excessive health resource utilization.[1] Recent estimates from the United States show that on any given day approximately 1 of every 25 inpatients in acute care hospitals has at least one HAI.[2] In Europe HAIs also represent a considerable burden, with more than 2.5 million cases occurring each year, resulting in approximately 2.5 million disability-adjusted life years.[3] Given the significant burden of HAIs with the potential for adverse outcomes in patients, there is much interest in understanding their transmission, prevention, and control. One particular issue is the relationship between levels and types of staffing of health facilities and HAIs. A number of organizational factors that influence the risk of HAIs have been identified, including nurse-to-patient ratio, level of nurse education, and job type (that is, temporary or permanent).[4–9] While nurses in particular are tasked with the responsibility of providing daily bedside patient care, all health care workers are responsible for applying infection prevention and control practices to prevent HAIs.[4]

Examining the association between hospital staffing and HAIs is not without challenges as it requires the use of standardized HAI case definitions, adequate data sources, and complex risk adjustment methods.[9] Furthermore, the web of causation linking staffing and HAI is difficult to understand and may include factors such as the complexity of the infection process, lack of time to comply with infection control measures, and job-related burnout.[9] Methodological issues in studies examining the association between hospital staffing and adverse outcomes have also been identified. These include lack of application of standardized definitions of nurse staffing, different databases, and diverse risk adjustment methods.[10] In addition, the temporal relationship between staffing and HAI occurrence has recently been noted as a methodological problem in studies examining hospital staffing and HAI.[11] HAIs are by definition infections that occur 48 hours after hospital admission.[11] Hence, staffing levels should be examined about 48 hours prior to detectable infection and not when the HAI is detected.

In 2008 a systematic review was undertaken to examine the relationship between hospital staffing and HAIs.[12] The researchers found that the majority of studies reported a significant association between the nurse staffing variable(s) studied and risk of HAIs. Since the completion of that review, there has been a growing interest in infection prevention and control research, particularly research into HAI prevention.[13] Further, this previous review included articles published up to 2007, and there have been numerous articles exploring staffing and the risk of infection published since that date. Understanding and synthesizing the most recent research on

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hospital staffing and HAI risk will inform health administrators, policy makers, and researchers on strategies for preventing HAIs and thereby improving patient outcomes. This systematic review therefore aims to examine the association between hospital staffing and patients' risk of developing HAIs in hospital settings.

METHODS

A systematic review of the literature was undertaken to identify publications that examine the relationships between hospital staffing and patients' risk of developing an HAI in the hospital setting. The approach used is consistent with a previous systematic review of this topic.[12] Reporting of this systematic review complied with the preferred reporting items for systematic reviews and meta-analyses (PRISMA) guidelines.[14]

Protocol and Registration

The protocol for conducting this review was registered prior to commencement of the review and can be accessed on the international prospective register of systematic reviews (PROSPERO) (registration number: CRD42015032398).

Search Strategy

A systematic search of the literature was conducted according to the registered protocol. Electronic databases PubMed and the Cumulative Index to Nursing and Allied Health Literature (CINAHL) were searched for studies published between January 1, 2000, and November 30, 2015. The search was performed on December 7, 2015. A combination of Medical Subject Headings (MeSH) and free-text terms were used, including "infection control," "staffing," and "healthcare associated infection." For retrieved articles, a manual search of the reference lists was also performed to identify any additional studies. Searches were restricted to studies published in the English language only.

Selection Criteria

The inclusion criteria were all observational studies (cohort, case control, or cross-sectional) examining the relationship between staffing and HAI in hospital settings. Randomized control trials were not available for inclusion. Given the complex and multifaceted nature of HAI and the ethical concerns about randomizing nurse staffing, conducting randomized control trials on this topic is often not feasible.[13] Studies describing health care staffing at the unit or organizational levels using variables such as level of staffing (number of staff, staff-to-patient ratio, staff hours per patient-day, years of experience, educational level), skill mix, use of float or nonpermanent staff, absenteeism and/or overtime, and workload were included. Exclusion criteria included grey and non-peer reviewed literature, reviews, editorials, commentaries or policy statements, articles reporting on community-acquired infections, and articles written in languages other than English.

Definitions

For the purpose of this systematic review, the following definitions were used:

- *Hospital staffing* was defined as nurse staffing, medical staffing, or infection prevention and control staffing.
- *Nurse staffing levels* were described using one or more of the following variables: level of staffing (nurse-to-patient ratio or nursing hours per patient-day or admission), skill mix, use of float or nonpermanent staff, absenteeism and/or overtime, workload.
- *Health care–associated infections* comprised bloodstream infection, pneumonia, urinary tract infection, wound or surgical site infection, organism-specific infections (for example, *Clostridium difficile* infection) that were defined as being health care–associated in the studies included in the review. The definition of HAI in the included studies was based on a recognized standard; that is, a definition agreed on or published by a professional association or government agency (for example, the Centers for Disease Control and Prevention [CDC]), a definition widely used in the published literature, or an International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM) code that constitutes an HAI (not just any infection).

Study Selection

The titles and abstracts of all articles identified were examined and assessed for relevance and appropriateness to the systematic review aim, and those not relevant were excluded. The full texts of potentially relevant articles were obtained to further assess eligibility based on the inclusion and exclusion criteria. Articles with data relevant to the systematic review were included. The electronic database search and study selection process were performed by trained research assistants. At each stage of the study selection process, 10% of articles retrieved were selected at random and reviewed by the study lead author as a cross-check against study eligibility. Any discrepancies in the application of the inclusion or exclusion criteria were resolved by the lead author. In addition, any disagreements between study authors in regard to the definitions were resolved by discussion with all authors.

Data Extraction

A data extraction form in Microsoft Excel (Microsoft Corp., Redmond, Washington) was designed for the purpose of extracting data for the systematic review. For each eligible study, the following data were extracted: author(s), year of publication, country of study, study design, study population, unit of analysis (patient, unit, or hospital), sample, setting, staffing category studied, staffing data source, staffing variables and parameters, type of HAI, HAI definition, and HAI

incidence or prevalence data. Data extracted were crossed-checked by a different research assistant.

Risk of Bias

An assessment of study quality and risk of bias in the articles included in the review was conducted using the Newcastle–Ottawa Scale.[15,16] The content validity and inter-rater reliability of this tool has been established.[16] One reviewer undertook this assessment independently, with a random 10% of articles reviewed by a second reviewer. No discrepancies were identified.

Data Analysis

Extracted data from included studies were synthesized and summarized in evidence tables. Summary tables include studies that examined nurse staffing and single site–specific HAI, nurse staffing and multiple types of HAI, nurse staffing and organism-specific HAI, nurse staffing and unspecified HAI, and non-nurse staffing and HAI. Given the heterogeneity of the studies included in the systematic review, pooling of data in a meta-analysis was not feasible.

RESULTS

Overview

The literature search yielded a total of 1,247 articles. After excluding duplicates and reviewing the titles and abstracts, there were a total of 90 articles remaining for full text review. The 90 articles were screened against the study inclusion and exclusion criteria. A total of 35 articles were excluded because they were reviews, editorials, commentaries or policy statements, or articles reporting on community-acquired infections. Fifty-four studies met the inclusion criteria and were included in the final systematic review (Figure 1).

Study Characteristics

Data on the characteristics of the 54 included studies are presented in a supplementary table (Appendix 1, available in online article). Of the 54 studies, 29 (53.7%) were undertaken in the United States. Half the studies ($n = 29$; 53.7%) used a cohort (retrospective or prospective) or longitudinal study design. Analysis of data was performed for most of the studies at the patient level ($n = 28$; 51.9%). The most common HAIs studied were bloodstream infection

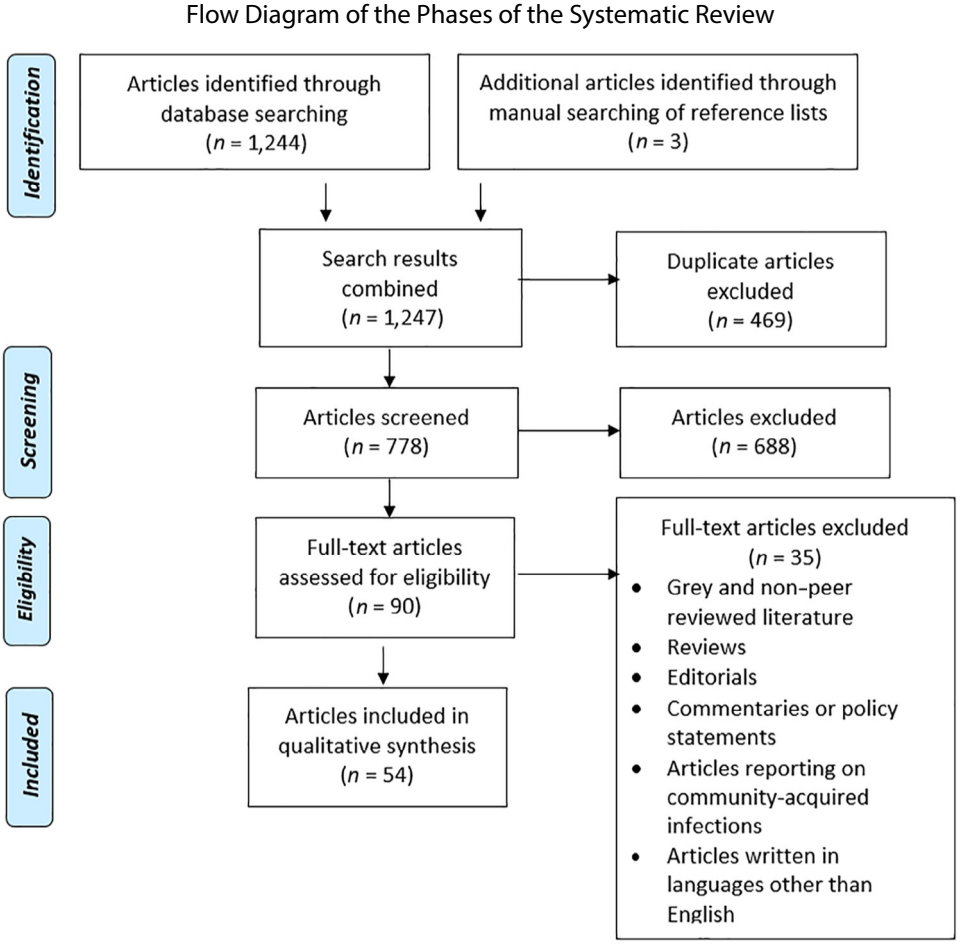

Figure 1: This flow diagram provides the phases of article identification and selection, which resulted in the identification of 54 articles that were deemed eligible for inclusion. Prepared in accordance with Moher D, et al. Preferred reporting items for systematic reviews and meta-analyses: The PRISMA statement. J Clin Epidemiol. 2009;62:1006–1012.

(BSI) ($n = 30$; 55.6%), pneumonia ($n = 24$; 44.4%), urinary tract infection (UTI) ($n = 21$; 38.9%), and wound infection ($n = 8$; 14.8%). The most frequent type of hospital staff examined were nurses ($n = 50$; 92.6%). Of these, the majority ($n = 40$; 74.1%) found a significant association between the nurse staffing variable(s) studied and HAI risk. The number of stars awarded to studies as part of the risk of bias assessment ranged from three to nine, with the full assessment presented in a supplementary table (Appendix 2, available in online article). Twenty-one of the 54 articles received five or more stars. Studies were of moderate quality, however, as many of the included studies did not control for potential confounders (comparability). All studies were included in the review, regardless of the risk of bias assessment. As no meta-analysis was performed and there was considerable heterogeneity in the study methods, no further subanalysis of results based on the risk of bias assessment was undertaken.

Nurse Staffing and a Single Site–Specific Infection

Table 1 presents the 9 studies in which the researchers examined nurse staffing and a single site–specific infection. Seven research teams examined BSI,[5,17–22] 1 group examined UTI,[23] and the remaining study examined ventilator-associated pneumonia (VAP).[24] Most of the research teams undertook data analysis at the patient level ($n = 7$; 77.8%), the majority in the ICU ($n = 6$; 66.7%). In 4 of the 7 studies investigating the association between level of nurse staffing and risk of HAI in patients, the investigators reported a significant association.[17,20,23,24] There were 2 studies in which the researchers examined the effect of using float or pool nurses on risk of acquisition of BSI.[5,20] In both of these studies, the researchers found a significant increase in the risk of BSI with a higher use of float nurses. In addition, 1 study found a decrease in BSIs after the introduction of a dedicated total parenteral nutrition surveillance clinical nurse manager.[18]

Nurse Staffing and Multiple HAIs

There were 26 studies that examined the relationship between nurse staffing and multiple HAIs (Table 2), which were primarily BSI ($n = 22$), UTI ($n = 20$), pneumonia ($n = 21$), and wound infection ($n = 7$).[7,10,25–48] In 12 of the studies (46.2%), the researchers aggregated data at the hospital level, with sample sizes ranging from 3 hospitals to 3,357 hospitals.[7,10,25–34] The operational definition of HAI was based on the ICD-9-CM codes for more than half of the studies ($n = 15$; 57.7%). In 22 (84.6%) studies, nurse staffing (skill mix, level, overtime, or float) was found to be associated with the risk of HAI; however, the results varied for these studies in regard to the measure of nurse staffing variable and HAI investigated. Numerous studies examined or included more than one nurse staffing variable.[7,25,30,31,34–41] No clear pattern was identified with respect to whether one particular nurse staff variable was more likely to be associated with a change in the risk of a HAI.

Nurse Staffing and Organism-Specific HAIs

Researchers examined nurse staffing and organism-specific HAIs in 6 studies (Table 3). Most of the research teams ($n = 4$; 66.7%) focused on methicillin-resistant *Staphylococcus aureus* (MRSA).[49–52] All except 1 study[51] analyzed data at the patient level, with 4 of those 5 studies being conducted in an ICU setting. An association was found between the level of staffing or skill mix and risk of HAI acquisition in 5 of the 6

Table 1. Studies Examining Nurse Staffing and Single Site–Specific Infection*

Type of Infection	Author (Year)	Unit of Analysis	Sample	Setting	Design	HAI Definition	Staffing	Statistically Significant Association
BSI	Alonso-Echanove et al.[5] (2003)	Patient	4,535	ICU	Cohort	CDC	F	Yes
	Cimiotti et al.[17] (2006)	Patient	2,675	NICU	Cohort	CDC	L	Yes
	Fraher[18] (2009)	Patient	1,932	Hospital	Cohort	IDSA	Other	Yes
	Pronovost et al.[19] (2001)	Patient	2,606	ICU	Cross-sectional	ICD	L	No
	Robert et al.[20] (2000)	Patient	127	ICU	Case-control	CDC	L/F	Yes/Yes
	Tucker[21] (2002)	Patient	13,334	NICU	Cohort	Other	L	No
	Whitman et al.[22] (2002)	Unit	95	Specialty units	Prospective observational	CDC	L	No
UTI	Sujijantararat et al.[23] (2005)	Unit	19	Hospital	Prospective, descriptive correlational design	Other	L/SM	Yes/No
VAP	Hugonnet et al.[24] (2007)	Patient	2,470	ICU	Cohort	CDC	L	Yes

HAI, health care–associated infection; BSI, bloodstream infection; CDC, Centers for Disease Control and Infection; F, float (use of float or nonpermanent staff); NICU, neonatal ICU; L, level of staffing (the authors assessed nurse-to-patient ratio or nursing hours per patient-day or admission; IDSA, Infectious Diseases Society of America; Other, other examples such as infection levels before and after introduction of a specialist nurse; ICD, International Classification of Diseases; UTI, urinary tract infection; SM, skill mix; VAP, ventilator-associated pneumonia.

*References can be found on pages 621–622.

Table 2. Studies Examining Nurse Staffing and Multiple Health Care–Associated Infections*

Author (Year)	Unit of Analysis	Sample	Setting	Design	HAI Definition	Staffing	Statistically Significant Association			
							BSI	UTI	Pneum	Wound
Amaravadi et al.[42] (2000)	Patient	366	ICU	Cohort	ICD	L	Yes	-	Yes	No
Barkell et al.[43] (2002)	Patient	96	Surgical unit	Retrospective descriptive comparison	CDC; Other	SM	-	No	No	-
Bae et al.[35] (2015)	Unit	12	ICU	Longitudinal	CDC	L/SM	No/No	-	No/No	-
Berney et al.[25] (2006)	Hospital	161	Hospital	Longitudinal	ICD	L/OT	Yes/No	No/No	No/Yes	-
Cimiotti et al.[25] (2012)	Hospital	161	Hospital	Cross-sectional	CDC	L	-	Yes	-	-
Dimick et al.[44] (2001)	Patient	569	Hospital	Cohort	ICD	L	No	-	No	No
Glance et al.[45] (2012)	Patient	70,142	Hospital	Cross-sectional	ICD	SM	Yes	-	Yes	-
Kelly et al.[27] (2013)	Hospital	320	Hospital	Cross-sectional	Other	L	Yes	Yes	Yes	-
Kendall-Gallagher et al.[36] (2009)	Unit	48	ICU	Cross-sectional	Other	SM/L	No/No	Yes/No	-	-
Kovner et al., 2002	Hospital	570	Hospital	Cross-sectional	ICD	L	-	No	Yes	-
Mark et al.[30] (2004)	Hospital	422	Hospital	Longitudinal	ICD	L/SM	Yes/No	No/No	Yes/No	-
Mark et al.[29] (2007)	Hospital	286	Hospital	Longitudinal	ICD	L	-	No	Yes	-
Mark et al.[10] (2010)	Hospital	283	Hospital	Longitudinal	ICD	L	No	No	No	-
McGillis Hall et al.[46] (2004)	Unit	77	Adult medical, surgical, and obstetric units	Descriptive correlational	Other	SM	-	No	-	Yes
Needleman et al.[7] (2002)	Hospital	799	Hospital	Cross-sectional	ICD	L/SM	No/No	Yes/Yes	No/Yes	No/No
Needleman et al.[31] (2003)	Hospital	3,357	Hospital	Cross-sectional	ICD	L/SM	No/No	No/Yes	Yes/Yes	-
Pappas et al.[47] (2015)	Unit	1	Surgical unit	Pretest posttest design	Other	L	No	No	-	-
Roche, et al.[37] (2012)	Unit	14	Medical and surgical wards	Longitudinal	ICD	L/SM	No/Yes	No/Yes	No/Yes	-
Schwab et al.[41] (2012)	Unit	182	ICU	Cohort	CDC	L/O	No/Yes	-	No/Yes	-
Stone et al.[38] (2007)	Patient	15,902	ICU	Cross-sectional	CDC	L/OT	Yes/No	No/Yes	Yes/No	-
Stratton[39] (2008)	Unit	34	Medical, surgical, oncology, and ICU	Descriptive, correlational, linear mixed model design	CDC	SM/OT/F	Yes/Yes/Yes	-	-	-
Twigg et al.[32] (2011)	Hospital	3	Hospital	Cohort	ICD	L	Yes	No	Yes	No
Unruh[33] (2003)	Hospital	Pennsylvania hospitals	Hospital	Longitudinal	ICD	L/SM	Yes/Yes	No/Yes	Yes/Yes	No/No
Unruh et al.[34] (2012)	Hospital	124	Hospital	Longitudinal	ICD	L	Yes	-	-	-
Yang et al.[40] (2003)	Unit	21	Medical-surgical units	Descriptive correlation study	Other	L/SM	-	Yes/No	No/No	-
Yang et al.[48] (2012)	Patient	487	Hospital	Retrospective	Not reported	SM	Yes	Yes	No	-

HAI, health care–associated infection; BSI, bloodstream infection; UTI, urinary tract infection; Pneum, pneumonia; ICD, International Classification of Diseases; L, level of staffing (the authors assessed nurse-to-patient ratio or nursing hours per patient-day or admission); CDC, Centers for Disease Control and Prevention; SM, skill mix; Other, other examples such as infection levels before and after introduction of a specialist nurse; OT, overtime; F, float (use of float or nonpermanent staff).

*References can be found on pages 621–622.

Table 3. Studies Examining Nurse Staffing and Organism-Specific Health Care–Associated Infections*

Author (Year)	Unit of Analysis	Sample	Setting	Design	Organism	HAI Definition	Staffing	Statistically Significant Association
Dancer et al.[49] (2006)	Patient	174	ICU	Retrospective analysis	MRSA	Other	L	No
Dorsey et al.[53] (2000)	Patient	52	ICU	Cohort	*Enterobacter cloacae* and *Serratia marcescens*	Other	L	Yes
Grundmann et al.[50] (2002)	Patient	331	ICU	Cohort	MRSA	Other	L	Yes
Kong et al.[52] (2012)	Patient	61	ICU	Cohort	MRSA	Other	L	No
Manojlovich et al.[51] (2011)	Unit	26	Adult medical and surgical units	Cohort	MRSA	Other	L/SM	Yes/Yes
Stegenga et al.[54] (2002)	Patient	2,929	General pediatrics ward	Retrospective descriptive	Viral gastrointestinal infection	CDC	L	Yes

HAI, health care–associated infection; Other, other examples such as infection levels before and after introduction of a specialist nurse; MRSA, methicillin-resistant *Staphylococcus aureus*; L, level of staffing (the authors assessed nurse-to-patient ratio or nursing hours per patient-day or admission); SM, skill mix; CDC, Centers for Disease Control and Prevention.
*References can be found on pages 621–622.

studies.[49–51,53,54] One study examined both skill mix and the level of staffing on the risk of MRSA infections and found both variables to be significant predictors.[51]

Nurse Staffing and an Unspecified HAI Type

Table 4 describes studies that examined nurse staffing and an unspecified HAI type. These studies either did not provide information on the specific HAI evaluated or grouped different HAI types in one analysis. There were 8 studies identified in this category. Two studies also assessed physician staffing in addition to nurse staffing.[55,56] Most researchers undertook data analysis at the patient level ($n = 6$; 75.0%), conducted their studies in an ICU ($n = 6$; 75.0%), and measured the level of nurse staffing ($n = 7$; 87.5%). All investigators found a significant association between the nurse staffing variable measured (level[55,57–62] and overtime[56]) and risk of HAI acquisition.

Non-Nurse Staffing and HAI

An overview of the 5 studies that examined non-nurse staffing and HAI is presented in Table 5. The non-nurse staffing types evaluated in these studies were ICU physicians[63,64] and infection control professionals (ICPs).[65,66] One study included both physicians and ICPs.[67] Only 1 of the 3 studies

Table 4. Studies Examining Nurse Staffing and Health Care–Associated Infections (Unspecified Infection Type)*†

Author (Year)	Unit of Analysis	Sample	Setting	Design	HAI Definition	Staffing	Statistically Significant Association
Andersen et al.[55] (2009)‡	Patient	57,360	Hospital	Point prevalence	CDC	L	Yes
Daud-Gallotti et al.[57] (2012)	Patient	195	ICU	Cohort	CDC	L	Yes
Halwani et al.[58] (2006)	Patient	430	ICU	Longitudinal	CDC	L	Yes
Hugonnet et al.[61] (2007)	Patient	1,883	ICU	Cohort	CDC	L	Yes
Hugonnet et al.[62] (2007)	Patient	366	ICU	Case-crossover, case-time-control, and cohort designs	CDC	L	Yes
Maillet et al.[59] (2014)	Patient	1,410	ICU	Retrospective evaluation	Other	L	Yes
Rogowski et al.[60] (2013)	Unit	67	ICU	Cohort	Other	L	Yes
Virtanen et al.[56] (2009)‡	Unit	60	Gen unit	Cross-sectional	CDC	OT	Yes

HAI, health care–associated infection; CDC, Centers for Disease Control and Prevention; L, level of staffing (the authors assessed nurse-to-patient ratio or nursing hours per patient-day or admission); Other, other examples such as infection levels before and after introduction of a specialist nurse; Gen unit, general ward; OT, overtime.
*References can be found on pages 621–622.
†The type of health care–associated infections included in each study varied but were grouped together for analysis.
‡Also included physicians.

Table 5. Studies Examining Non-Nurse Staffing and Health Care–Associated Infections*

Author (Year)	Unit of Analysis	Sample	Setting	Design	Staffing Type	Staffing	Type of Infection	HAI Definition	Statistically Significant Association
Dimick et al.[63] (2001)	Patient	366	Hospital	Cohort	Physician	Other	BSI, Pneumonia, Postoperative infection (not specified)	ICD	No/No/No
Geubbels et al.[67] (2005)	Hospital	36	Hospital	Cohort	ICP/Physician	L/L	Wound infection	CDC	No/No
Parikh et al.[64] (2012)	Patient	2181	ICU	Cohort	Physician	L	VAP/Central venous access device infection	CDC	Yes/Yes
Richet et al.[65] (2003)	Hospital	90	Hospital	Cross-sectional	ICP	L	MRSA	Other	Yes
UK Neonatal Staffing Study Group[66] (2005)	Patient	13,334	NICU	Prospective, observational study	ICP	L	BSI	Other	Yes

HAI, health care–associated infection; Other, other examples such as infection levels before and after introduction of a specialist nurse; BSI, bloodstream infection; ICD, International Classification of Diseases; ICP, infection control professional; L, level of staffing (the authors assessed nurse-to-patient ratio or nursing hours per patient-day or admission); CDC, Centers for Disease Control and Prevention; VAP, ventilator-associated pneumonia; MRSA, methicillin-resistant *Staphylococcus aureus*; NICU, neonatal ICU.
*References can be found on pages 621–622.

that examined the level of physician staffing and risk of HAI found a statistically significant association.[64] Two of the 3 studies that examined the level of ICP staffing and risk of HAI found an association.[65,66]

DISCUSSION

This article provides a comprehensive systematic review of the recent literature, examining the relationships between staffing and HAI rates. Overall, results were consistent with a previous systematic review on this topic,[12] which found staffing to be significantly linked to the risk of HAI acquisition in the majority of included studies. Due to methodological differences and challenges in studies included in this review, a meta-analysis was not possible. The findings from our study highlight the current trends in the relationship of staffing and HAI rates, alongside emphasizing the need for standardized definitions of staffing and HAIs, more rigorous study designs, and risk-adjusted HAI data.

Interest in HAIs has been increasing internationally, due to the burden they create and to their potentially adverse outcomes in patients.[1–3] However, although multiple studies investigating the relationship between staffing and HAIs have been published since the last systematic review was undertaken,[12] the findings in our study were largely similar. There still seems to be a lack of consistent and rigorous study designs, which is predominantly manifested in the use of observational studies, rather than randomized control trials, as the latter are often not feasible or ethical.[13] A small majority of studies included in our review, used longitudinal designs, such as prospective or retrospective cohort designs that allow conclusions for certain trends in the data but no causal inferences, as bias in the form of confounding variables cannot be excluded. Furthermore, methodological flaws, including varying operational definitions of HAIs and staffing, the use of different databases (that is, nationally available / state-level administrative data vs. unit- and hospital-based data from nursing services, nursing departments and payroll), and diverse risk adjustment methods, compound interpretation of results and impede meta-analysis.

Overall, the findings suggest staffing to be associated with HAIs; increased levels of staffing seem to be connected to a decrease in the risk of acquiring HAIs. Staffing was mainly measured as level of staffing (nurse-to-patient ratio or nursing hours per patient-day), with other studies using measures such as skill mix, overtime, and the use of float nurses. Operational definitions for HAIs were based on either ICD-9-CM codes or on definitions from the CDC. However, other definitions for HAIs were used, potentially reflecting practice with the country in which the study was undertaken. The use of varying measures and definitions, as well as other methodological flaws and design limitations, as mentioned above, may explain the mixed results.

The vast majority of studies included in this review investigated relationships between nurse staffing and HAIs, with only a small number of studies examining non-nurse staffing (that is, physicians and ICPs). Remarkably, only one of three studies investigating relationships between level of physician staffing and risk of HAIs identified an association between the level of physician staffing and VAP and central venous access device infections.[64] In the two other studies, no association was found between level of physician staffing and wound infection,[67] and no association was found between physician staffing defined as daily rounds of a physician, and multiple HAIs (BSI, pneumonia, not specified postoperative infection), based on ICD-9-CM code.[63] Our findings

are consistent with a previous review that also did not identify a statistically significant link between physician staffing and HAIs.[12] If these results are to be taken at face value, one explanation may be that nurses constitute the largest proportion of the health care workforce and have considerable patient contact,[11] thus providing an opportunity for increased risk of organism transmission. As such, nurses have the unique opportunity to directly reduce HAIs through recognizing and applying evidence-based procedures to prevent HAIs among patients and protecting the health of the staff.[4]

In studies that examine the association between nurse staffing and the risk of HAIs, a differentiation between permanent nurse staffing and nonpermanent (temporary or float) staffing is often made. Consistent with previous findings,[12] the majority of studies in our review suggested that the use of permanent nurse staff was connected to a decrease in risk of HAI acquisition. Conversely, the use of nonpermanent nurse staff was linked to an increase in HAI risk. However, evidence on the effects of using nonpermanent staff is scarce, with our study identifying only three studies exploring this association.[5,20,39] To explain this result, it is plausible that nonpermanent nurse staff are less familiar with ward routine and infection prevention strategies, may lack specific training, and may not have the same level of communication with coworkers due to the inability to form established relationships.[12] The importance of clear, interdisciplinary communication and collaboration among health care professionals has been highlighted by several studies,[68–70] with poor communication being named as one of the most common causes for medical errors (that is, HAIs).[68,69]

Our review identified a lack of studies exploring the relationship of specialized staff, including ICPs. The CDC's Study on the Efficacy of Nosocomial Infection Control (SENIC), which suggested an adequate staffing ratio of ICPs to patients, was published more than four decades ago.[71] Given the high interest in HAIs and the number of studies examining staffing and HAIs published in the last decade, this scarceness of evidence is problematic; however, the challenges in undertaking a study such as the SENIC Project cannot be understated. Only three studies included in our review examined associations between ICPs and HAIs, and only one study examined the effect of a specialist nurse on risk of HAI acquisition.[18] Results were mixed, but two of the three studies examining the effect of ICPs on the risk of acquiring HAIs found statistically significant associations.[65,66] Similarly, researchers who examined the associations between the use of a specialist nurse and HAIs found a decrease in BSIs after introduction of a dedicated parental clinical surveillance clinical nurse manager. These findings suggest that the use of specialized staff is a positive factor in the prevention of HAIs. It is possible that specialized staff experiences increased accountability and responsibility, due to clear set tasks related to infection prevention assigned to them. The importance of accountability and responsibility of health care professionals for patient safety has been introduced into health care as the "problem of many hands."[72] Practical applications of this problem have been demonstrated through the introduction of checklists to improve different groups of health care professionals' compliance with infection prevention.[73] Future research is needed to establish a body of evidence to support the tentative link between specialized nurse staffing and ICPs and HAI rates.

Our review has limitations. Non–peer reviewed literature, reviews, editorials, and commentaries or policy statements and articles were excluded to maintain rigour and consistency of the study. Publications in a language other than English were also excluded. As such, evidence from such research was not included. Further, no meta-analysis, and therefore assessment of publication bias, was undertaken due to the methodological limitations of the included studies. A further challenge in exploring this topic is understanding a hospital's investment areas such as infrastructure, personnel, and activities aimed at promoting quality. These are potential confounders that are not easily controlled or quantified, as evidenced by the risk of bias assessment. With the trend of shorter lengths of stay, patients have increased acuity and may need a higher level of care; however, in this review we were not able to examine staffing ratios adjusted for patient acuity.[74]

CONCLUSION

Despite the data being observational, there is a growing and updated evidence base demonstrating the relationship between staffing characteristics and HAIs. The findings support advocacy for effective use of staffing resources and will inform health care managers and professional organizations on future changes to hospital staffing, as they relate to infection prevention. Considerable variability in the study design, methods, and definitions used to examine staffing and the risk of HAIs exist in the literature. This highlights the need to move to uniform operational definitions of staffing and HAIs in future studies that explore this area.

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Conflicts of Interest. One of the authors [P.W.S.] was a lead author on an article included[38] in this review. She played no role in the selection of articles against the inclusion/exclusion criteria. The other authors all report no conflicts of interest.

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ONLINE-ONLY CONTENT

See the online version of this article for Appendix 1 Characteristics of Studies Included in the Systematic Review. Appendix 2 Risk of Bias Assessment in the Studies in the Systematic Review.

REFERENCES

1. Allegranzi B, et al. Burden of endemic health-care-associated infection in developing countries: systematic review and meta-analysis. Lancet. 2011 Jan 15;377:228–241.
2. Magill SS, et al. Multistate point-prevalence survey of health care–associated infections. N Engl J Med. 2014 Mar 27;370:1198–1208.
3. Cassini A, et al. Burden of six healthcare-associated infections on European population health: estimating incidence-based disability-adjusted life years through a population prevalence-based modelling study. PLoS Med. 2016 Oct 18;13:e1002150.
4. Collins AS. Preventing health care–associated infections. In: Hughes RG, editor. Patient Safety and Quality: An Evidence-Based Handbook for Nurses. Rockville, MD: Agency for Healthcare Research and Quality, 2008 Accessed Apr 26, 2018. https://www.ncbi.nlm.nih.gov/books/NBK2683/.
5. Alonso-Echanove J, et al. Effect of nurse staffing and antimicrobial-impregnated central venous catheters on the risk for bloodstream infections in intensive care units. Infect Control Hosp Epidemiol. 2003;24:916–925.
6. Jackson M, et al. Nurse staffing and health care–associated infections: proceedings from a working group meeting. Am J Infect Control. 2002;30:199–206.
7. Needleman J, et al. Nurse-staffing levels and the quality of care in hospitals. N Engl J Med. 2002 May 30;346:1715–1722.
8. Aiken LH, et al. Educational levels of hospital nurses and surgical patient mortality. JAMA. 2003 Sep 24;290:1617–1623.
9. Hugonnet S, et al. Nursing resources: a major determinant of nosocomial infection? Curr Opin Infect Dis. 2004;17:329–333.
10. Mark BA, Harless DW. Nurse staffing and post-surgical complications using the present on admission indicator. Res Nurs Health. 2010;33:35–47.
11. Shang J, Stone P, Larson E. Studies on nurse staffing and health care–associated infection: methodologic challenges and potential solutions. Am J Infect Control. 2015;43:581–588.
12. Stone PW, et al. Hospital staffing and health care–associated infections: a systematic review of the literature. Clin Infect Dis. 2008 Oct 1;47:937–944.
13. Dettenkofer M, et al. Infection control—a European research perspective for the next decade. J Hosp Infect. 2011;77:7–10.
14. Moher D, et al. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. J Clin Epidemiol. 2009;62:1006–1012.
15. Higgins J, Green S. Cochrane Handbook for Systematic Reviews of Interventions, ver. 5.1.0. Chichester, UK: Wiley; The Cochrane Collaboration, 2011.
16. Ottawa Hospital. The Newcastle-Ottawa Scale (NOS) for Assessing the Quality of Nonrandomised Studies in Meta-Analysis. Wells GA, et al. 2014. Accessed Apr 26, 2018. http://www.ohri.ca/programs/clinical_epidemiology/oxford.asp.
17. Cimiotti JP, et al. Impact of staffing on bloodstream infections in the neonatal intensive care unit. Arch Pediatr Adolesc Med. 2006;160:832–836.
18. Fraher MH, et al. Cost-effectiveness of employing a total parenteral nutrition surveillance nurse for the prevention of catheter-related bloodstream infections. J Hosp Infect. 2009;73:129–134.
19. Pronovost PJ, et al. Intensive care unit nurse staffing and the risk for complications after abdominal aortic surgery. Eff Clin Pract. 2001;4:199–206.
20. Robert J, et al. The influence of the composition of the nursing staff on primary bloodstream infection rates in a surgical intensive care unit. Infect Control Hosp Epidemiol. 2000;21:12–17.
21. Tucker J, UK Neonatal Staffing Study Group. Patient volume, staffing, and workload in relation to risk-adjusted outcomes in a random stratified sample of UK neonatal intensive care units: a prospective evaluation. Lancet. 2002 Jan 12;359:99–107.
22. Whitman GR, et al. The impact of staffing on patient outcomes across specialty units. J Nurs Adm. 2002;32:633–639.
23. Sujijantararat R, Booth RZ, Davis LL. Nosocomial urinary tract infection: nursing-sensitive quality indicator in a Thai hospital. J Nurs Care Qual. 2005;20:134–139.
24. Hugonnet S, Uçkay I, Pittet D. Staffing level: a determinant of late-onset ventilator-associated pneumonia. Crit Care. 2007;11(4):R80.
25. Berney B, Needleman J. Impact of nursing overtime on nurse-sensitive patient outcomes in New York hospitals, 1995–2000. Policy Polit Nurs Pract. 2006;7:87–100.
26. Cimiotti JP, et al. Nurse staffing, burnout, and health care–associated infection. Am J Infect Control. 2012;40:486–490. Erratum in: Am J Infect Control. 2012;40:680.
27. Kelly D, et al. The critical care work environment and nurse-reported health care–associated infections. Am J Crit Care. 2013;22:482–488.
28. Kovner C, et al. Nurse staffing and postsurgical adverse events: an analysis of administrative data from a sample of U.S. hospitals, 1990–1996. Health Serv Res. 2002;37:611–629.
29. Mark BA, Harless DW, Berman WF. Nurse staffing and adverse events in hospitalized children. Policy Polit Nurs Pract. 2007;8:83–92.
30. Mark BA, et al. A longitudinal examination of hospital registered nurse staffing and quality of care. Health Serv Res. 2004;39:279–300. Erratum in: Health Serv Res. 2004;39:1629.
31. Needleman J, et al. Measuring hospital quality: can Medicare data substitute for all-payer data? Health Serv Res. 2003;38:1487–1508.
32. Twigg D, et al. The impact of the nursing hours per patient day (NHPPD) staffing method on patient outcomes: a retrospective analysis of patient and staffing data. Int J Nurs Stud. 2011;48:540–548.
33. Unruh L. Licensed nurse staffing and adverse events in hospitals. Med Care. 2003;41:142–152.
34. Unruh LY, Zhang NJ. Nurse staffing and patient safety in hospitals: new variable and longitudinal approaches. Nurs Res. 2012;61:3–12.
35. Bae SH, et al. Use of temporary nursing staff and nosocomial infections in intensive care units. J Clin Nurs. 2015;24:980–990.
36. Kendall-Gallagher D, Blegen MA. Competence and certification of registered nurses and safety of patients in intensive care units. Am J Crit Care. 2009;18:106–113. quiz 14.
37. Roche M, et al. Nursing work directions in Australia: does evidence drive the policy? Collegian. 2012;19:231–238.

38. Stone PW, et al. Nurse working conditions and patient safety outcomes. Med Care. 2007;45:571–578.
39. Stratton KM. Pediatric nurse staffing and quality of care in the hospital setting. J Nurs Care Qual. 2008;23:105–114.
40. Yang KP. Relationships between nurse staffing and patient outcomes. J Nurs Res. 2003;11:149–158.
41. Schwab F, et al. Understaffing, overcrowding, inappropriate nurse:ventilated patient ratio and nosocomial infections: which parameter is the best reflection of deficits? J Hosp Infect. 2012;80:133–139.
42. Amaravadi RK, et al. ICU nurse-to-patient ratio is associated with complications and resource use after esophagectomy. Intensive Care Med. 2000;26:1857–1862.
43. Barkell NP, Killinger KA, Schultz SD. The relationship between nurse staffing models and patient outcomes: a descriptive study. Outcomes Manag. 2002;6:27–33.
44. Dimick JB, et al. Effect of nurse-to-patient ratio in the intensive care unit on pulmonary complications and resource use after hepatectomy. Am J Crit Care. 2001;10:376–382.
45. Glance LG, et al. The association between nurse staffing and hospital outcomes in injured patients. BMC Health Serv Res. 2012 Aug 9;12:247.
46. McGillis Hall L, Doran D, Pink GH. Nurse staffing models, nursing hours, and patient safety outcomes. J Nurs Adm. 2004;34:41–45.
47. Pappas S, et al. Risk-adjusted staffing to improve patient value. Nurs Econ. 2015;33:73–78, 87.
48. Yang PH, et al. The impact of different nursing skill mix models on patient outcomes in a respiratory care center. Worldviews Evid Based Nurs. 2012;9:227–233.
49. Dancer SJ, et al. MRSA acquisition in an intensive care unit. Am J Infect Control. 2006;34:10–17.
50. Grundmann H, et al. Risk factors for the transmission of methicillin-resistant *Staphylococcus aureus* in an adult intensive care unit: fitting a model to the data. J Infect Dis. 2002 Feb 15;185:481–488.
51. Manojlovich M, et al. Nurse dose: linking staffing variables to adverse patient outcomes. Nurs Res. 2011;60:214–220.
52. Kong F, et al. Do staffing and workload levels influence the risk of new acquisitions of meticillin-resistant *Staphylococcus aureus* in a well-resourced intensive care unit? J Hosp Infect. 2012;80:331–339.
53. Dorsey G, et al. A heterogeneous outbreak of *Enterobacter cloacae* and *Serratia marcescens* infections in a surgical intensive care unit. Infect Control Hosp Epidemiol. 2000;21:465–469.
54. Stegenga J, Bell E, Matlow A. The role of nurse understaffing in nosocomial viral gastrointestinal infections on a general pediatrics ward. Infect Control Hosp Epidemiol. 2002;23:133–136.
55. Andersen BM, et al. Hospital-acquired infections before and after healthcare reorganization in a tertiary university hospital in Norway. J Public Health (Oxf). 2009;31:98–104.
56. Virtanen M, et al. Work hours, work stress, and collaboration among ward staff in relation to risk of hospital-associated infection among patients. Med Care. 2009;47:310–318.
57. Daud-Gallotti RM, et al. Nursing workload as a risk factor for healthcare associated infections in ICU: a prospective study. PLoS ONE. 2012;7:e52342.
58. Halwani M, et al. Cross-transmission of nosocomial pathogens in an adult intensive care unit: incidence and risk factors. J Hosp Infect. 2006;63:39–46.
59. Maillet JM, et al. Comparison of intensive-care-unit-acquired infections and their outcomes among patients over and under 80 years of age. J Hosp Infect. 2014;87:152–158.
60. Rogowski JA, et al. Nurse staffing and NICU infection rates. JAMA Pediatr. 2013;167:444–450.
61. Hugonnet S, Chevrolet JC, Pittet D. The effect of workload on infection risk in critically ill patients. Crit Care Med. 2007;35:76–81.
62. Hugonnet S, Villaveces A, Pittet D. Nurse staffing level and nosocomial infections: empirical evaluation of the case-crossover and case-time-control designs. Am J Epidemiol. 2007 Jun 1;165:1321–1327.
63. Dimick JB, et al. Intensive care unit physician staffing is associated with decreased length of stay, hospital cost, and complications after esophageal resection. Crit Care Med. 2001;29:753–758.
64. Parikh A, et al. Quality improvement and cost savings after implementation of the Leapfrog intensive care unit physician staffing standard at a community teaching hospital. Crit Care Med. 2012;40:2754–2759.
65. Richet HM, et al. Are there regional variations in the diagnosis, surveillance, and control of methicillin-resistant *Staphylococcus aureus*? Infect Control Hosp Epidemiol. 2003;24:334–341.
66. UK Neonatal Staffing Study Group. Relationship between probable nosocomial bacteraemia and organisational and structural factors in UK neonatal intensive care units. Qual Saf Health Care. 2005;14:264–269.
67. Geubbels EL, et al. Hospital-related determinants for surgical-site infection following hip arthroplasty. Infect Control Hosp Epidemiol. 2005;26:435–441.
68. Tschannen D, et al. Implications of nurse-physician relations: report of a successful intervention. Nurs Econ. 2011;29:127–135.
69. Siegele P. Enhancing outcomes in a surgical intensive care unit by implementing daily goals tools. Crit Care Nurse. 2009;29:58–69.
70. Lancaster G, et al. Interdisciplinary communication and collaboration among physicians, nurses, and unlicensed assistive personnel. J Nurs Scholarsh. 2015;47:275–284.
71. Haley RW, et al. The SENIC Project. Study on the efficacy of nosocomial infection control (SENIC Project). Summary of study design. Am J Epidemiol. 1980;111:472–485.
72. Dixon-Woods M, Pronovost PJ. Patient safety and the problem of many hands. BMJ Qual Saf. 2016;25:485–488.
73. Haynes AB, et al. A surgical safety checklist to reduce morbidity and mortality in a global population. N Engl J Med. 2009 Jan 29;360:491–499.
74. Dharmarajan K, et al. Declining admission rates and thirty-day readmission rates positively associated even though patients grew sicker over time. Health Aff (Millwood). 2016 Jul 1;35:1294–1302.